

## N O T I C E

THIS DOCUMENT HAS BEEN REPRODUCED FROM  
MICROFICHE. ALTHOUGH IT IS RECOGNIZED THAT  
CERTAIN PORTIONS ARE ILLEGIBLE, IT IS BEING RELEASED  
IN THE INTEREST OF MAKING AVAILABLE AS MUCH  
INFORMATION AS POSSIBLE

(NASA-CR-164171) UNDERSTANDING THE LANDSAT  
MARKET IN DEVELOPING COUNTRIES Final Report  
(Stanford Univ.) 86 p HC A05/MF A01

DR1  
N81-21439

CSSL 08F

Unclas

G3/43 29613



PROGRAM IN INFORMATION POLICY

ENGINEERING-ECONOMIC SYSTEMS DEPARTMENT

STANFORD UNIVERSITY • STANFORD, CALIFORNIA 94305



**UNDERSTANDING THE LANDSAT MARKET  
IN DEVELOPING COUNTRIES**

**Matthew R. Willard**

**Report No. 30**

**November 1980**

**National Aeronautics and Space Administration**

**Contract NASW 3204**

**PROGRAM IN INFORMATION POLICY**

**Engineering-Economic Systems Department  
Stanford University                      Stanford, California 94305**

## CONTENTS

	<u>page</u>
1. OVERVIEW . . . . .	1
2. INTRODUCTION . . . . .	2
3. THE TECHNOLOGY OF LANDSAT . . . . .	8
The Space Segment . . . . .	8
The Ground Segment . . . . .	12
4. THE USER SEGMENT, CONSTRAINTS ON MARKET DEVELOPMENT IN DEVELOPING COUNTRIES . . . . .	17
Resource Information Needs in Developing Countries	17
The Development Project Cycle: Constraints on Market Development . . . . .	22
User Needs: Types of Surveys . . . . .	24
Summary . . . . .	31
5. POLITICAL AND INSTITUTIONAL CONSTRAINTS ON THE DEVELOPING COUNTRY MARKET FOR LANDSAT PRODUCTS . . . . .	33
Domestic Institutional Factors . . . . .	33
Institutional Constraints . . . . .	35
The "Familiarity With Technology" Constraint . . . . .	38
Political Constraints on the Use of Landsat Data in Developing Countries . . . . .	41
The issues of Sovereignty and Economic Exploitation . . . . .	42
The Issues of Dependence and Accountability . . . . .	47
6. POLICY ISSUES AND TRADE OFFS . . . . .	50
 <u>Appendix</u>	 <u>page</u>
A. RESOURCE INFORMATION AREAS . . . . .	57
B. THE MAPPING POTENTIAL OF LANDSAT . . . . .	66
C. LANDSAT POLICY APPLICATIONS . . . . .	72

D.	FOR AGRICULTURAL CROPS . . . . .	75
E.	SIMPLE VS. COMPLEX RESOURCE AREAS . . . . .	78
F.	METHODS FOR ORGANIZING NATIONAL REMOTE SENSING PROGRAMS . . . . .	81

## 1. OVERVIEW

The National Oceanic and Atmospheric Administration (NOAA) recently headed an interagency task force to determine the technical parameters and institutional arrangements for a U.S. operational earth resource sensing system. One of the most important and least understood inputs confronting the task force was the market for Landsat products and ground processing equipment. While the U.S. government represents somewhat over half of the 1979 market (about 52%), the foreign segment of the market is substantial (about 36%), and is expected to grow rapidly.<sup>1</sup> In particular, the developing nations of the world represent a large potential market for Landsat data and products. This paper is an effort to understand the Landsat market in developing countries, and the constraints on the growth of that market which stem from the development process itself and from a country's technical, political and institutional attributes.

-----

<sup>1</sup> Private Sector Involvement in Civil Space Remote Sensing, NASA Headquarters, June, 1979, (cited hereafter as the PSIS study), see also Planning For a Civil Operational Land Remote Sensing Satellite System: A Discussion of Issues and Options, NOAA Headquarters, June 1980, (cited hereafter as Issues and Options).

## 2. INTRODUCTION

Four competing factors guide the development of policy regarding an operational land remote sensing system, and it is important to outline them at the outset, for they provide the broad societal context for the analysis in this paper:

- 1) there is a need to boost U.S. exports in areas where the U.S. holds a technological lead;
- 2) the need to develop user applications in developing countries on their terms coincides with a foreign policy imperative to maintain good relations with third world nations;
- 3) developing countries desire to take control of their own development and the types of technology and industry which they adopt;<sup>2</sup> and
- 4) the U.S. government wants to enlist the participation of major companies in the management, operation and ownership of the operational system. Such participation requires a substantial world-wide market. A more in-depth look at these four factors follows.

First, declining U.S. productivity and the decline of U.S. technological superiority in many international markets impels the U.S. to take advantage of any technological lead which it holds. There is, as well, an economic imperative

-----

<sup>2</sup> Lately there has been a shift in rhetoric from an emphasis on GNP growth and the "trickle down" theory of development to the meeting of basic human needs. While this is of course not universally true, the principle of the theoretic shift has been accepted by the World Bank and other international institutions. See Baum, Warren, "The World Bank Project Cycle", in Finance and Development, 12/78.

in capitalist systems which calls for exploitation of a technological monopoly when it exists. Earth resource sensing satellites represent an area where the U.S. holds an edge over its nearest competitors. The French and the Japanese will not be launching experimental systems until the mid-1980's.<sup>3</sup> By that time the U.S. should have an interim-operational system based on the Landsat D spacecraft and sensor system in the air.<sup>4</sup> However, recent Congressional testimony suggests that foreign systems may, by leapfrogging primitive U.S. systems, catch up to or move ahead of U.S. systems technologically.<sup>5</sup> Foreign countries also may be tailoring their systems to the needs of the developing countries, thereby, cutting into the U.S. market share. Hence, one factor guiding U.S. decision-makers is that of supporting U.S. industry in a highly competitive world.

Second, in contrast to the strictly domestic economic needs of the country, the health of the international economic community demands the development of third world countries in an effort to stabilize a seemingly chaotic world situation. The recent Afghanistan crisis should not blind us to -----

<sup>3</sup> PSIS and Issues and Options op. cit.

<sup>4</sup> Ibid.

<sup>5</sup> See Statement by Mr. David Johnson, Director National Environmental Satellite Service, National Oceanographic and Atmospheric Administration, Department of Commerce, Before the Committee on Communication, Science and Transportation, Subcommittee on Science, Technology and Space, June 26, 1980.



the fact that the East-West cleavage in international relations has been fading in place of a growing north-south conflict over the call for a new international economic order. Even in the context of a renewed cold war, the U.S. will no longer be able to ignore the demands of the developing world if it hopes to maintain a viable foreign policy.

Third, there is a growing demand by third world nations to control their own development. As such, the profit motives of U.S. companies may run headlong into a host country's desire to develop its resources and population in a stable manner. For instance, even if Landsat data is the most cost-effective and most efficient way to obtain resource information, and we in the developed world would immediately adopt it it may not make any sense for a developing country with a huge labor surplus that could employ many people doing ground surveys. If the U.S. wants to develop markets in third world nations, it may have to do so on terms set to some extent by those nations.

Fourth, the National Aeronautics and Space Administration is in the process of transferring the operational earth resources sensing program to the Department of Commerce's National Oceanic and Atmospheric Administration (NOAA). As a part of that transfer NOAA must initiate private sector involvement, and deal with international participation.

Work done thus far<sup>6</sup> on private sector and foreign involvement has focused on efforts to determine how to entice companies into owning and operating the operational system. Following the example of the communications satellite industry, one might conjecture, the government would continue to pursue long-term R&D, while the private sector would pursue applied R&D and market development. However, unlike the communications industry, a multi-billion dollar market does not already exist. To find a company of sufficient size to be interested in making the investment required would demand that a market for resource sensing products be fairly apparent. Showing that market may be a difficult task as many U.S. government agencies have said that a market price would sorely limit the adoption of Landsat technology by federal, state and local government users.<sup>7</sup> Therefore, a fourth factor that guides the policy process is the need to demonstrate that a sufficient market can be developed to support corporate investment in the space segment of an operational earth resource sensing system.

-----

<sup>6</sup> In private discussions with NASA personnel, I was told of the studies presently being undertaken as a part of the transition plan effort.

<sup>7</sup> see State and Local Government Perspectives on a Landsat Information System, prepared by the Natural Resource and Environmental Task Force on the Intergovernmental Science, Engineering, and Technology Advisory Panel, June 1978, pg. 36, hereafter cited as the ISETAP report.

This paper is an attempt to illuminate the constraints on the Landsat market in developing countries. These constraints play an important role in potential market projections, and will therefore be important to understand as policy regarding the system characteristics and government/industry interface is made.

I intend to place the discussion of the potential Landsat<sup>4</sup> market in developing countries in the context of resource information for development planning. The reason for this is simple: resource information is essential to successful development planning (in all countries, not just developing countries). Landsat technology and products are one way amongst several for acquiring that data, and Landsat may or may not be the most effective and cost-efficient method available. Hence, the real market which private sector firms in this country must deal with is the market for development planning, of which resource information is a vital part. Therefore, building a viable Landsat market in developing countries will depend on its use in development planning, and such planning rests inevitably on the particular characteristics of the country involved.

This study is divided into four parts. Chapter 3 of this study reviews the technology of Landsat, including the space and ground segments. In much of the literature on remote

sensing, there has been an unfortunate overemphasis on Landsats' technology and potential. Chapter 4 of this study concentrates on the user segment, and in particular, on the constraints inherent in the development process which limit the market for Landsat data. It will generally point out that there is a "user need" for Landsat type data but that the development of that need into a viable market is constrained by present technology and indigenous factors.

Chapter 5 focuses on the institutional and political constraints impacting the adoption of Landsat technology in developing countries.

Finally, Chapter 6 will take a tentative look at the trade-offs confronting U.S. policy makers as they formulate Landsat policy in the context of the four guiding factors discussed on preceding pages. At that point, preliminary suggestions for future study will be discussed.

### 3. THE TECHNOLOGY OF LANDSAT

In simplest terms, Landsat consists of three critical segments-- the space segment, the ground segment and the user segment. The space segment consists of the satellite, the sensors, the ground based satellite control equipment and software. The ground system consists of data reception facilities, data processing facilities and information extraction/image interpretation. A third critical segment is the user community. This segment is treated in Chapters 4 and 5.

#### 3.1 THE SPACE SEGMENT

The Landsat satellite is a 950 kilogram spacecraft which orbits the earth at an altitude of about 560 miles. It orbits the earth 14 times a day and returns to the same orbit once every eighteen days. The 14 strips of the earth's surface covered each day by Landsat are each about 185 kilometers wide (115 miles). Each day the satellite passes over a strip 170 kilometers west of a strip surveyed on the previous day, and senses it. This provides a 15 km overlap which can be important if there is a problem with

cloud cover or other atmospheric interference on any given day.<sup>8</sup>

There are two sensor systems on all of the Landsat's which have been launched to date. Landsat's 1 and 2 each had return beam vidicon (RBV) system and a multi-spectral scanner (MSS). The RBV system consists of three television like cameras aimed to view the same 185 by 185 km ground area simultaneously. These cameras have a nominal ground resolution of 80 meters and the spectral bands designated bands 1, 2, and 3 on Landsat cover the following parts of the electromagnetic spectrum:

band 1 (green)	.46 to .60 um
band 2 (red)	.57 to .68 um
band 3 (near infrared)	.66 to .82 um. <sup>9</sup>

However, on Landsats 1 and 2 the RBV systems were used relatively little; they will be more thoroughly tested on Landsat 3.<sup>10</sup> The MSS records information in both the visible and in parts of the electromagnetic spectrum which are invisible

-----

<sup>8</sup> Remote Sensing From Space, Prospects For Developing Countries, National Academy of Sciences, Washington D.C., 1977, pg. 39,40. hereafter cited as the NAS study. see also Lillesand and Kiefer Remote Sensing and Image Interpretation, New York, John Wiley and Sons, 1977.

<sup>9</sup> NAS study, op. cit., pg 45.

<sup>10</sup> Ibid. pg. 43.

to the human eye and to the camera systems. The MSS takes four readings for each 1.1 acre area on the ground--one for the intensity of green light reflected, one for the intensity of red light reflected, and two for the intensity of infrared light reflected. The four bands of the MSS overlap some with the bands of the RBV, but are designated as bands 4, 5, 6 and 7. They cover the electromagnetic spectrum as follows;

band 4 (green)	.5 to .6 um
band 5 (red)	.6 to .7 um
band 6 (infrared)	.7 to .8 um
band 7 (near infrared)	.8 to 1.1 um

Landsat 3, launched in 1978, contained two major changes from the previous Landsats. First a thermal channel (10.4 to 12.6 um) was added to the MSS, and second, the spatial resolution of the RBV system was improved to 30 m. However, shortly after launch the thermal channel developed operating problems, hence the MSS on-board the spacecraft is operating in essentially the same mode as the previous Landsats.<sup>11</sup> While the effective resolution of Landsat images is about 79m on the MSS images, and about 30m on the RBV images, depending on the interpretation technique being used, narrow linear objects with distinct spectral characteristics can

-----

<sup>11</sup> Lillesand and Keifer, op. cit. , pg. 540.

often be detected. On the other hand objects much larger than 79m across may go undetected if they blend with their surroundings so that features are not spectrally distinct.<sup>12</sup>

The space system also includes two wideband video recorders which collect and store the data acquired in areas beyond the range of the receiving stations. This data is held until the receiving station comes back into view of the satellite and is then dumped to the station. Each recorder can handle either RBV or MSS data. On Landsat's one and two, only one of the four recorders worked regularly, making it difficult to receive data from areas not in sight of the satellite when it passed near a receiving station.<sup>13</sup>

The MSS has the following characteristics which make it different and sometimes better than conventional purposes for remote sensing:

1. data is available in digital form making large amounts of data rapidly processible by computer;
2. the original data, in digital form, can easily and rapidly be transferred to other receiving stations, unlike a film original;

-----  
<sup>12</sup> Ibid, pg 544.

<sup>13</sup> Nat. Study, op. cit., pg 46.



3. they can acquire data in the infrared region which is beyond the capability of regular cameras.

However, the high resolution camera is still superior in some cases for disclosing the identity, shape, and appearance of many small objects or features.<sup>14</sup>

### 3.2 THE GROUND SEGMENT

The ground segment involves three activities: data reception, data processing and data interpretation.

#### Data reception:

There are presently ten ground stations capable of receiving Landsat data--of which three are located in the United States, two are in Canada, and one each in Italy, Brazil, Argentina, Japan and Sweden. The operators outside the U.S. simply tell NASA when they wish to have the MSS turned on over their station. The station can receive Landsat data while the satellite is within their "line of sight"--a radius of about 3000 km. This allows each station to receive a total of about 28 million km sq. during one Landsat pass. (This is the total footprint of the Landsat as it passes within the stations line of sight.)<sup>15</sup>

- - - - -

<sup>14</sup> Ibid, pg 50.

### Data processing:

There are three primary products which can be made out of the Landsat data. black and white imagery is produced at the earth resources observations (EROS) data center in several forms: first, there are 55.8 by 55.8 cm. negative and positive transparencies at a scale of 1:3,369,000, and 18.5 by 18.5 cm film and print enlargements at 1:1,000,000; second, there are print enlargements 37 cm by 37 cm at a scale of 1:500,000 or 74 cm by 74 cm at 1:250,000.<sup>16</sup> The second Landsat products are color composites. These take advantage of the fact that the human eye can distinguish many hundreds of color variations. Hence, by applying different variations of colors to the variations of grey in the negative, a color composite can be produced.

The third product developed from Landsat data are computer compatible tapes (CCT'S). These tapes preserve all the intensity levels of the MSS (a total of 64) in digital form. The CCT's can then be fed into a computer for digital analysis of the spectral properties in order to produce desired information in tabular form. The tapes can also be used to -----

<sup>15</sup> Issues and Options, op.cit.

<sup>16</sup> Ibid, pg. 55. A scale of 1:250,000 = 1 in/4 mi;  
1:500,000 = 1 in/8 mi; 1:1,000,000 = 1 in/16 mi.

produce thematic maps emphasizing one or another selected ground features.<sup>17</sup>

In performing digital analysis of Landsat data, there are three types of computer based procedures that can be used:<sup>18</sup>

1. image restoration: these operations act to "restore" distorted image data to a more "faithful" representation of the original scene;
2. image enhancement: prior to displaying image data for visual analysis, enhancement techniques can be applied to accentuate the apparent contrast between features in the scene. In many applications this greatly increases the amount of information that can be visually interpreted from the image data;
3. image classification: quantitative techniques can be applied to automatically interpret digital image data. In this process, each pixel observation is evaluated and assigned to an information category, thus replacing the image data file with a matrix of category types.

-----  
<sup>17</sup> Ibid, pg. 56.

<sup>18</sup> Lillesand and Kiefer, Op. Cit., pg. 557.

### Data Interpretation:

Data interpretation usually begins with the detection and identification of important objects. The objects are then measured manually or with the aid of appropriate instruments. This measurement is then considered in light of the interpreter's particular expertise. Then the interpreter must be able to communicate both his perception of and the significance of the object identified.<sup>19</sup> Various methods of extracting information from remotely sensed data can be used. In sequence from least to most expensive and sophisticated they are:

1. manual interpretation of standard photographic products using very simple, inexpensive instruments;
  2. manual interpretation aided by photographic enhancement and employing more costly optical equipment;
  3. manual interpretation of special digitally enhanced photographic products using the equipment as described in step 2;
  4. digital analysis of the computer compatible tapes in a process of man-machine interactions to produce the desired computer output, which is in turn subjected to further human interpretation and analysis.<sup>20</sup>
- 

<sup>19</sup> Estes, John, "A Perspective on the State of the Art of Photographic Interpretation", in International Symposium on Remote Sensing of the Environment, vol 11, ERIM, 1977, pg 161-176.

<sup>20</sup> NAS, Op. Cit., pg 55-56.

Finally, image interpretation and particularly information extraction may be aided by the "multi-concept" of data interpretation. This includes multi-station (Landsat, aerial, and ground surveys used together), multi-temporal sampling (different time periods using the same sensing unit), multi-stage sampling (which means simply acquiring data at different scales) and multi-band sampling (simply using different bands to look at the same scene).

Landsat's technology, from the space and ground segment provides at least five advantages over traditional surveying techniques. First, it views the earth synoptically; second, its repetitive coverage allows it to maintain up to date information; third, its computer compatibility allows its data to be merged with other information about population and terrain in order to produce more complete land-use and resource planning maps; fourth, its uniformity over time allows it to take comparative pictures which enhances the ability of planners to detect change. and fifth, its multi-spectral scanner allows it to observe different aspects of the same object, or to distinguish between two objects that might otherwise be missed. These advantages provide exciting potential. However, one must look to the user segment to determine if that potential will be realized.

#### 4. THE USER SEGMENT, CONSTRAINTS ON MARKET DEVELOPMENT IN DEVELOPING COUNTRIES

##### 4.1 RESOURCE INFORMATION NEEDS IN DEVELOPING COUNTRIES

The ultimate objectives of collecting natural resource information are

1. to aid countries in the evaluation of investment prospects;
2. to provide information to be used for improving current management of natural resources;
3. to aid in the performance of certain governmental activities (particularly the administration of land taxes and the like).<sup>21</sup>

I am primarily interested in the first two objectives, and later on I will explore them in the context of a development project. However, a central question is: what kinds of objectives and resource information needs drive developing country investment and management decisions? The following examples suggest the types of development objectives out of which the need for resource information is generated.

-----

<sup>21</sup> Herfindel, Orris, Natural Resource Information for Economic Development Resources for The Future, Washington D.C., Johns Hopkins Press, Baltimore, 1969, pgs 20-21.

## Tanzania

Much of Tanzania's economic development effort is directed toward agriculture and animal husbandry. Principal resource data requirements in Tanzania tied to immediate needs include:

1. land use and land capability (distribution of soils and vegetation types) information to determine suitability for farming or range;
2. structural geology and groundwater information, as linked to soils, vegetation, and topographic data, to help locate additional water sources, to increase the efficiency of well digging and water impoundment schemes, and to help in the siting of new villages; and
3. monitoring of land and range stress due to drought or overgrazing to permit rehabilitation of these resources.<sup>22</sup>

## Venezuela

Venezuela's development plans call for continued industrialization, further exploration of mineral and petroleum deposits, improved land use and quality of life in urbanized areas, colonization of frontier area, greater emphasis on investment in agriculture, including expanded assistance to the rural poor and placement of more land under irrigation. To accomplish these objectives, Venezuela's data collection efforts emphasize:

1. land use and urban change;
2. pollution assessment of beaches and coastal area;
3. further mapping of geologic structures to aid in mineral exploration and siting of mine related construction projects;

-----

<sup>22</sup> NAS Study, Op. Cit., pg.29.

4. classification of soils and vegetation in current and potential agricultural areas; determination of crop acreage and changes in crop and
5. monitoring of seasonal water coverage of lands being considered for new settlement, agricultural development and improvement.<sup>23</sup>

## Costa Rica

The use of land for agricultural purposes has been the backbone of Costa Rica's economy for several centuries. As Costa Rica's industrial and economic base grows, increasing pressures are put upon agricultural and range land, and in turn upon the forest lands of the nation. Thus, prime agricultural areas are being threatened by urban expansion and areas predominantly suited to forestry are being converted to marginally productive range and agricultural uses.

This conversion is not controlled or monitored. Costa Rica's need for resource information in order to control this type of urban spread is not unique to developing countries. They require information to monitor and update their land use maps, in order to better manage their own domestic growth and expansion.<sup>24</sup>

---

<sup>23</sup> Ibid., pg. 30.

<sup>24</sup> Craib, Ken, et al., "Application of Remote Sensing Techniques to Forest Vegetation Surveys in Tropical Areas and Urban Fringe Land Use Problems in Costa Rica", in International Symposium of Remote Sensing of Environment, vol. 12, pg 2091, 1978. (hereafter cited as ERIM symposium)



## Sri Lanka

In Sri Lanka, development planners in the mid 1970's began a program to develop new agricultural land in order to reach self-sufficiency in agricultural production and food consumption. Land-use maps had last been updated in the early 1960's, and many smaller farms were not recorded.

The agricultural program has as its goals:

1. crop breeding;
2. multiple cropping;
3. soil conservation; and
4. improved management of agricultural lands.

An agricultural base-mapping program was required to provide information on soils, present vegetation, land-use for siting of new agricultural areas, and topography for assistance in irrigation planning and watershed management.<sup>25</sup>

The importance of natural resources to economic development is clear, particularly as a country strives for self-sufficiency. While trade enables many nations to acquire resources which it does not possess internally, natural resources and information about those resources is essential in planning and implementing development projects.<sup>26</sup> Appendix A contains a detailed list of resource information needs.

-----

<sup>25</sup> "Agricultural Resource Inventory and Base Mapping in Sri Lanka, A Program Evaluation and Assessment", Resource Development Associates, Los Altos, Ca., 11/76.

<sup>26</sup> Herfindel, Op. Cit., pg 4.

In order to successfully design and complete a development project, then, knowledge of the resource base is essential. This is the context within which the market for resource information products in developing countries exists. In sum, according to a national Academy of Science study,

the process of economic development consists largely of organizing the development and productive exploitation of natural resources in the interests of the whole community. To do so effectively a nation needs to know what resources it has and where they are, and it needs to have a fairly detailed grasp of its overall physical environment. For many developing countries, this knowledge base is limited, fragmentary, dispersed, and on the whole, less than adequate for the purposes of sound national development. The capability to acquire, store, analyze and use natural resource information for broadly developmental purposes still eludes many developing nations. Most nations at present are seeking to acquire better resource information.<sup>27</sup>

The above quotation stresses that the type of resource information needed varies not only with the type of resource to be monitored, but with the end-use of that information as well. The surveys themselves do not represent the end-use of the data collected. Rather, the way data is used to make decisions about resource management in particular and development planning in general, represent the actual end-use of remotely sensed data.

-----  
<sup>27</sup> NAS study, Op. Cit., pg 24; See Appendix B for a discussion of Landsat applications in developing countries.

#### 4.2 THE DEVELOPMENT PROJECT CYCLE: CONSTRAINTS ON MARKET DEVELOPMENT

Developmental decisions are usually related to specific development projects. Such projects go through at least four distinct phases, including project identification, project planning, project implementation, and project evaluation.<sup>28</sup>

The identification phase must be "carried out first to determine the human needs as well as the availability of renewable and nonrenewable resources required to prepare a development project."<sup>29</sup> The planning phase takes information on the nations infrastructure, existing capabilities, collected resource information and the countries political, social and financial status into account in designing an appropriate project. This stage is followed by the implementation phase, which varies in length according to the type of project and the sector to which it is related.<sup>30</sup> The project evaluation phase, sometimes called the project appraisal phase, includes an on-going social, political, economic, institutional and financial analysis of the

-----

<sup>28</sup> Adrien, Pierre, and Alfonso Blandon, "Economic Overview of Remote Sensing Applications in Development Projects", in Proceedings of the Second Conference on the Economics of Remote Sensing, Craib and Watkins (eds.), Resources Development Associates, Los Altos, Cal., January 1978. (cited hereafter as Second Conference)

<sup>29</sup> Ibid., pg 21.

<sup>30</sup> Ibid., pg 22.

project. In general, The World Bank has found that the most difficult phase of the project cycle is the implementation of development projects.<sup>31</sup>

This problem continues to affect developing countries and is directly connected to the project planning phase. Whenever the latter is poorly conceived, the chance of successful completion of a project become rather slim.

This suggests that as countries adopting Landsat remote sensing technology go through the development project phases described above, appropriate utilization of Landsat technology will depend to some extent on the wisdom and ability of project planners. It is also especially important for understanding the development of a Landsat market to realize that all phases of a resource development project cycle require resource information, particularly in the identification and planning phases.<sup>32</sup> The following chart outlines the types of remote sensing applications used in the different project phases, with the type of survey (to be further defined in a moment) required at each phase noted to the right.<sup>33</sup>

-----

<sup>31</sup> Ibid. pg. 22.

<sup>32</sup> See Appendix C for a discussion of potential Landsat applications in specific substantive areas pertinent to development.

<sup>33</sup> Ibid. pg 26, with my additions.

**Illustration of Remote Sensing Utilization  
in the Development "Project Cycle"**

<u>Project Phases or Cycles</u>	<u>Examples of Applications</u>	<u>Type of Survey</u>
I. Project Identification	Natural resources identification and quantification; comprehensive resource inventory; obtention of timely reliable information through visual and digital analysis.	Reconnaissance
II. Project Planning	Examination of change in project resource base; assessment of potential benefits or problems.	Semi-detailed
III. Project Implementation/Monitoring	Role of technology rather limited, except if allocation and management of large volume of resource information are involved, such as natural or regional land use projects.	Detailed
IV. Project Evaluation (post)	Diversified uses in assessing the utilization of one or more natural resources in project development.	Combination of Reconnaissance, semi-detailed, detailed, depending on project.

#### 4.3 USER NEEDS: TYPES OF SURVEYS

Using the above chart we can divide resource information needs into three broad categories: reconnaissance surveys, semi-detailed surveys, and detailed surveys.<sup>34</sup> For each type

<sup>34</sup> Other authors have used different labels for the various surveys. Throughout this paper I will use these, however they correspond to other common labels as follows: pre-investment=semi-detailed, inventories for operational

of survey, mapping requires progressively larger scale maps.  
(See Table Below.)

<u>Type of Survey</u>	<u>Map Scale</u>
Detailed	1:15,840 (4 in./mile)
Semi-Detailed	1:20,000-1:63,360 (about 2 in./mile)
Reconnaissance	1:200,000-1:500,000 (about .1 in./mile)

Detailed maps are used, for example, in the use and management of soils. Semi-detailed maps are required for agricultural development projects, irrigation development, drainage, land enhancement decisions, and for determining investment potential in agricultural development areas. Reconnaissance surveys are used for identifying areas for potential development activity.<sup>35</sup> However, these general guidelines vary from resource to resource and country to country. For instance, one study recently described agricultural and forest information surveys as follows.<sup>36</sup>

-----

management=detailed, and reconnaissance is usually just called reconnaissance.

<sup>35</sup> From informal discussions with personnel at Resources Development Associates. See also Herfindel, op. cit.

Reconnaissance--spatial/area information and data about the land  
its natural condition, occurrence and acreage of  
forest types, land use classes, crop types, etc.  
(to be cited later as category A)

Semi-detailed---qualitative information about growing crop  
species, tree species, species composition in  
natural or cultivated stands of vegetation,  
as well as about such stand quality aspects  
as vigor, healthiness, timber quality, etc.  
to be cited later as category P)

Detailed-----quantitative information and data about  
cultivated stands of vegetation, or natural  
but usable vegetation crops, timber volume  
and age, plantation density, grazing capacity,  
figures about the loss of a resource after  
a disaster, etc. (also to be cited later as  
category P)

The same study then produced the following table which generalizes, with respect to agricultural and forestry applications, the sources of various survey requirements.<sup>37</sup>

-----

<sup>36</sup> Hildebrandt, Gerd, "Application of Remote Sensing for Policy Planning and Management in Forestry and Agriculture", in Earth Observation Systems for Resource Management and Environmental Control, Clough and Morley (eds.), Plenum Press, N.Y., 1977, pg 254.

<sup>37</sup> Ibid. pg. 255.

## Survey Type

## Main Information Sources

	<u>Remote Sensing</u>			<u>Ground level field work</u>
	<u>Satellites</u>	<u>High altitude aircraft</u>	<u>Medium altitude aircraft</u>	
<u>Reconnaissance:</u>				
very large areas,	A	A	A	A
broad classes,	P	P	P	P
less details.				
<u>Pre-investment (semi-detailed):</u>				
large areas,	A	A	A	A
refined classes,		P	P	P
many details.				
<u>Inventories for Operational Management (detailed):</u>				
small areas,			A	A
detailed classes,			P	P
very many details.				

### Information Source Can Produce

A = Area mapping/classification  
P = Properties, quantitative  
and qualitative.

Note that as one moves from reconnaissance to detailed surveys, the information source and what it can deliver, shifts from an emphasis on satellites to medium and low altitude aircraft, and ground surveys. Hence, as one moves along in the project cycle from identification to implementation, satellites as an information source are likely to give way to medium and low flying aircraft, and ground surveys. How-



ever, for appraisal and evaluation purposes throughout the project, satellites may prove to be very important.<sup>38</sup>

In cutting into the resource information needs of developing countries then, we can segment the potential market for Landsat products by the type of survey required. With present technology, Landsat is fully able to meet the reconnaissance resource information needs of developing countries (except where data is unobtainable), and to partially meet their semi-detailed/pre-investment needs (this is a particularly grey area, depending to a large extent on the particular country involved).

-----

<sup>38</sup> I should qualify this statement a bit, because depending on the sophistication of the ground processing equipment and the user, and depending on the country and resource involved, this generalization may not hold.

### The Need For Repetitive Coverage

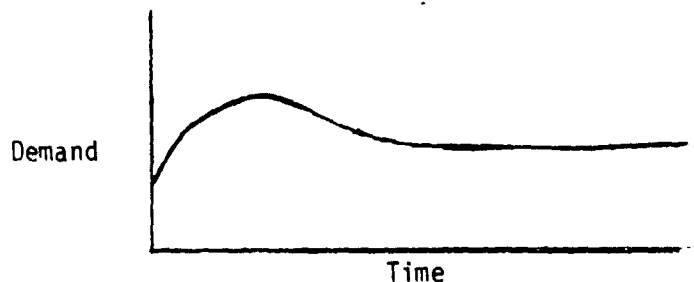
A closely related dimension along which the resource information needs of developing countries must be assessed is the frequency with which the data is required. For some applications data need only be gathered every few years while for other applications a survey may be required daily, weekly or monthly. Appendix D shows the frequency requirements for several application areas.<sup>39</sup>

One trade-off that is highlighted by the present study is that the kind of survey for which Landsat is best suited (reconnaissance) requires the least amount of repetitive coverage. More detailed surveys usually require more frequent coverage. So that while Landsat's 9 day (or 18 day with only one satellite) frequency of coverage makes it extremely attractive for some purposes, its relatively high spatial resolution makes it less attractive for those same purposes. The implications for the potential market of the requirement for repetitive coverage are found in the market projection presently being made by decision makers. If one-shot coverage at a reconnaissance level is all that is required, the market will not grow in a linear fashion as

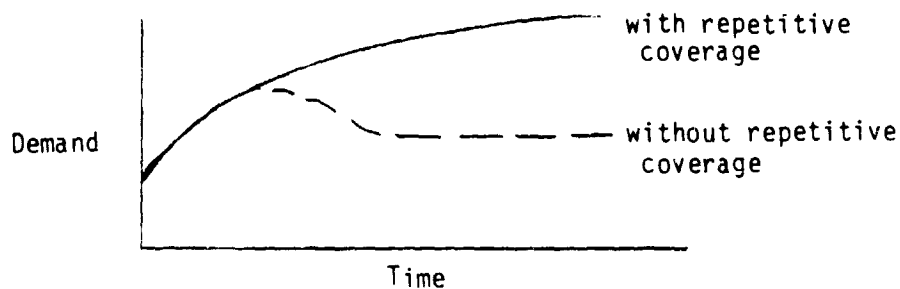
-----

<sup>39</sup> Colwell, Robert, "Globally Uniform Resource Surveys", in Earth Observation Systems For Resource Management and Environmental Control, op. cit., pg 194-195.

assumed in current government projections. Instead it will take on the following demand growth curve. This curve reflects "one-shot" users who will order Landsat data once or a very few times, then drop out of the market.



As various technological requirements (mainly for finer resolution) for more detailed data are met, the amount of repetitive data utilized will increase (due to use of the data throughout all phases of the development project cycle)--and the demand growth curve will more fully approximate the "linear growth" projected by government policy makers.<sup>40</sup>




---

<sup>40</sup> Issues and Options paper and PSIS study, op.cit.

#### 4.4 SUMMARY

While development information needs exist for all countries, the needs of individual countries vary according to several factors, including the size of the country, its type of geography, its development strategies and objectives, the type of resource information already available, the degree of detail that is needed, the present capacity of a country to use resource information, and whether data will be acquired once or repetitively. In sum, in determining the resource sensing information environment in developing countries, and hence the potential market for Landsat data, one must consider the following:

1. At what stage in the development cycle is a project? Does that stage require reconnaissance surveys, or more detailed resource information? In general one can think about the project cycle, extending along a continuum from project identification to project planning, project implementation, and evaluation. Generally as you move from development planning to project implementation the information needs become more specialized, calling for a closer and closer look.
2. Repetitive Coverage--Some projects require only infrequent resource surveys, while others will require them to be taken weekly, daily, or even more.

For instance, crop yield prediction requires at least bi-monthly overflight, while reconnaissance surveys may only need to be done every five years. Monitoring urban sprawl may require yearly pictures, while estimating disaster damage may require hourly response.

3. The type of resource to be monitored--some resources are more easily discernable than others, and this also will determine to some extent the timeliness requirement of the data. One particularly important determinant of the type of technology used for resource surveys, for example, is the simple or complex nature of the area to be observed. Appendix E outlines the difference between simple and complex areas in agricultural vegetation, range and forest vegetation, and geology, hydrology and soils.<sup>1</sup>

Along with the constraints of the resource development process and the type of resource to be monitored (and how often), one must also examine institutional and technological constraints when assessing the Landsat market. It is these constraints, as well as political questions regarding Landsat, to which I now turn.

-----

<sup>1</sup> Colwell, op. cit., pg 200,201.

## 5. POLITICAL AND INSTITUTIONAL CONSTRAINTS ON THE DEVELOPING COUNTRY MARKET FOR LANDSAT PRODUCTS

Further constraints on the development of a market for remote sensing products in developing countries take the form of political concerns and institutional limitations.

### 5.1 DOMESTIC INSTITUTIONAL FACTORS

The operational use of Landsat remote sensing data is not constrained so much by technical concerns as it is by manpower, institutional and equipment factors. It is in the routine use of data, not its collection, that the operational use of remote sensing data meets its toughest test.<sup>12</sup>

Therefore, there is a need to understand what internal institutional and technological capabilities exist in a given country, and what type of interpretation and analysis procedures will best serve a developing country's needs. In other words, one must understand the users present institutional environment to successfully build a user market in developing countries. A recent survey<sup>13</sup> (the Wallender report) of technology transfer cases developed a useful typ-

-----

<sup>12</sup> NAS Study, op. cit., pg 117.

<sup>13</sup> Wallender, Harvey, et. al., Technology Transfer and Management in Developing Countries, Ballinger Publishing Co., Cambridge, Mass., see Ch. 3.

ology of user environments in developing countries; this typology is summarized in Table 1.

TABLE 1

Development and Infrastructure

Stage Of Technological Development in Developing Countries	Objectives or Goals Within Each Stage That Must Be Achieved Before Proceeding To The Next Stage
-----	-----
1. Organization Development	1. Building an initial institutional structure.
	2. Building an internal problem solving and diagnostic planning capability.
2. Search and Acquisition	3. Problem Identification, and search for appropriate technology.
	4. Technology Acquisition
	5. Technology Application and use in decision making.
3. Maintenance and Modification	6. Maintaining and modifying technological and decision making structures as new technologies and problems arise.
4. Research, Development and Engineering	7. Development of internal technological capabilities.
	8. Spreading technology to other sectors of the country.

What the Wallender report suggests is that prior to building a self-supporting market for Landsat data in developing

countries, an institutional framework to support the use of Landsat is essential. Transferring or selling technology to end-users does little to help them achieve the objectives of organization development (stage 1) or technology search and acquisition (stage 2), and may in fact retard their movement toward self-reliance in maintenance and modification of technology and in R&D (Stages 3 and 4). The point is that many international technology transfer projects have overemphasized technology (useful in stages 3 or 4) and have failed to build an infrastructure or internal organization to support continued use of Landsat data.<sup>11</sup> The Wallender study concluded that efforts to build the technical capabilities associated with stages 3 and 4 will fail unless the objectives of stages 1 and 2 have been realized. Hence critical to the development of a self-supported Landsat market in developing countries is the development of indigenous institutional and technological capabilities.

## 5.2 INSTITUTIONAL CONSTRAINTS

From the Wallander typology, we can see that prior even to the development of the capability to identify problems and to search for appropriate solutions is the need for organizational development. This stage includes the building of  
-----

<sup>11</sup> Craib, Op. Cit., 1973, pg. 290.



an initial organizational structure, and the development of an internal problem solving and diagnostic planning capability. These two features of development may be thought of as the major institutional and manpower constraints on technological development. In the development of a long term market for Landsat products in developing countries, these two constraints must be overcome and effective strategies for overcoming them may rely little or not at all on applications of Landsat technology.

Because one Landsat scene can be used by many interested parties, including hydrologists, geologists, soils scientists, agricultural specialists, physical planners, geographers, there are economies of scale in promoting multiple uses of Landsat data. According to the National Academy of Sciences, "the more numerous and diversified the users of remote sensing are, the more economically feasible it is for a country to sustain a national analysis capability."<sup>4</sup> As such, with the interdisciplinary nature of development planning coupled with the technology's demand for interdisciplinary skills, the generation of organizational structures to effectively house such activities is crucial. Also, with limited manpower and budgetary resources, a focused resource information effort is needed. There are many ways of

-----

<sup>4</sup> NAS Study, op. cit., pg 125.

coordinating such activity, depending on the country involved, its needs, resources, and political situation.<sup>46</sup>

Hence for the development of a long term market, the development of an organizational infrastructure is critical. As with any technology transfer project in this or any other country, the user must be trained to stand on his own once the transfer agent has finished his job. In this case the transfer agent, be it the U.S. Agency for International Development (AID) or some private consulting firm, will not succeed until the developing country has developed an internal organization that can decide on its own to use Landsat products and Landsat technology. This is where a potential market will be transformed into a viable market. In other words, a market requires demand pull as well as technology push. Foreign aid spent on transferring technology might be better spent in the development of an institutional/organizational infrastructure conducive to using remote sensing data. Without successful technology transfer efforts which start at stage 1 in the technology development typology, market building is likely to fail.

-----

<sup>46</sup> See ERIM Symposium, Vol 12, for a review of many national remote sensing programs. Appendix F reviews some of the various methods used to coordinate national remote sensing programs.

### 5.3 THE "FAMILIARITY WITH TECHNOLOGY" CONSTRAINT

Closely related to the development of an effective organizational context is the need to thoroughly familiarize the users of the technology with the technology itself and its value for helping them perform their work. This primarily means training people and coordinating manpower and equipment. Generally there are two types of training: general and in-depth.

General training includes a balanced exposure to scientists and policy makers of what the technology is and what its limitations and advantages are. This type of exposure is essential to starting a country on a road toward the adoption of the technology. It usually preceeds a more formal, in-depth training stage.

In-depth training involves coupling the training of specialists in the fields to be explored (water resources, geology, etc.) with training in the interpretation of remotely sensed data. This process may be quite extensive and take several years. Such training is currently available from the developed countries and one concern of the developing nations is continued access to training programs and facilities.

In developing a long term market--in creating both the organizational infrastructure and internal problem-solving

capability--long-term, intensive training programs will have to be implemented. If this area is treated in a haphazard manner, the potential for developing Landsat users will be severely hampered. In discussions with Dr. Charles Poulton, former head of the remote sensing laboratory at Oregon State, and consultant at various times to U.S. AID and NASA, I was told of the importance of training programs which were intensive, hands-on, and long term enough to allow the individuals involved enough time to develop the confidence to "stand-alone." In his opinion this was one of the most, if not the most, critical step in building a market for Landsat data products.

One particularly successful training program has been developed between the Laboratory for Applications of Remote Sensing (LARS) at Purdue University and Bolivia.<sup>47</sup> As a result  
-----

<sup>47</sup> This program includes the following features:

1. Short Courses: A one week long course on the fundamentals of remote sensing.
2. Mini-courses: A series of modularized auto-tutorial units containing a broad range of sensing subjects that can be used in a variety of learning situations by students with diverse backgrounds.
3. Remote Terminal Network: Direct access to the LARS processing system is also available through remote terminals. A seven unit educational package usable from remote terminals is available for user training;
4. Visiting Scientists: A specialized course, varying from subject to subject, which offers in-depth training in various applications or scientific areas.

of this program, Bolivia now has a trained set of scientists who can perform their own analysis of Landsat data using sophisticated U.S. data processing equipment in their home country.<sup>18</sup>

The conclusions of this section are straightforward. The development of an effective market for Landsat products and technology will rely on effective technology transfer that encourages developing countries to adopt Landsat technology. Such technology transfer will be successful only if it assists in the development of an effective organizational context.<sup>19</sup>

-----

<sup>18</sup> Bartolucci and Brockman, Second Symposium, op. cit., pg. 48.

<sup>19</sup> One firm, Resources Development Associates (RDA), having undertaken many projects in developing countries, has developed a multi-stage technology transfer process which includes

1. Identification of user information needs;
2. Demonstration projects which determine the most effective technological approach for obtaining the required resource surveys;
3. A pilot project which develops an internal operational capability and the information base responsive to the country's needs and its capabilities to operate and maintain that information base;
4. Implementation--the development of a national project to conduct resource information surveys and aid decision makers.

However, the adoption of Landsat technology in developing countries also depends on political factors. It is to these factors that I now turn.

#### 5.4 POLITICAL CONSTRAINTS ON THE USE OF LANDSAT DATA IN DEVELOPING COUNTRIES

There are three main areas of political and legal concern that shape the development of a market in both developed and developing countries. First, sovereignty issues: here there are two foci, the question of whether a nation may engage in remote sensing of the territory of another nation without that nation's consent; and the question of whether the sensing nation has the right to transmit data generated from the observation of the territory of one nation to a third nation without the consent of the country sensed. Second, economic issues: will resource information be used to the detriment of the countries being sensed; i.e., will multi-national corporations be able to further exploit a country's resources to the detriment of that country's development goals? Third, dependence and accountability issues: devel-

-----

See "An Assessment of Resource Inventory and Environmental Problems in Costa Rica", Craib, 3/77, and "Design of a Natural Resource Inventory for Costa Rica, Pilot Project Report, 6/79, and Agricultural Resource Inventory and Base Mapping program in Sri Lanka: A Program Assessment and Evaluation", Craib and Cain, 11/76, (Los Altos, Ca., RDA).

oping countries are reluctant to have to rely on a single source for critical data. They are also concerned about who will be accountable for the reliability and continuity of the data. Here, I believe, are the most important issues to be encountered. How can developing countries avoid further and deeper dependence relations with developed countries, and at the same time assure themselves continued access to reliable and complete data?<sup>50</sup>

#### 5.5 THE ISSUES OF SOVEREIGNTY AND ECONOMIC EXPLOITATION

There are two primary sovereignty issues discussed throughout the legal and political debate in the United Nations over the development of remote sensing regulations. First is the desire of the developing countries to control the sensing of their territory. A set of draft principles which Argentina and Brazil jointly submitted to the U.N. Committee on the Peaceful Uses of Outer Space of the UN states "that states shall refrain from sensing the natural resources of -----"

<sup>50</sup> Before delving into these issues, one caveat is in order. Throughout this policy discussion, it is essential to remember, that while much talk goes on, the U.S. through Landsat 3, continues to sense the entire world and to make that data available to all countries. This should be kept in mind because many developing countries have shown that the use of Landsat to gather resource information, with all of its question marks and political hazards, is better than no information at all. By buying the data at this point, they are undercutting their primary bargaining chip, which is the withholding of their market from the U.S. companies.

another state without consent."<sup>51</sup> This issue is largely academic. Landsat technology is not bounded by the the relatively recent demarcation of state boundries drawn on the Earth, and to develop a sensor that could conform to such a demand would be prohibitively expensive. In any case, this move has been dropped.

Second, many countries desire control over the dissemination of data obtained about their country from remote sensing. This issue is the nexus of the argument in the UN debate; and a prohibition against open dissemination without consent is contained in the Argentina/Brazil draft, and also in the French/Russian set of draft principles regarding control of remote sensing from space.<sup>52</sup>

Concern over dissemination stems from the fact that "nations seem to fear the economic imperialism of the technologically developed countries, particularly with regard to exploitation of Landsat discovered and hitherto hidden resources, the existence of which might be unknown to a developing country."<sup>53</sup> This fear is questioned on three grounds:

-----  
<sup>51</sup> See U.S. Working Paper, "Remote Sensing of the Natural Environment of the Earth from Outer Space", UN Document /A/AC.105/C.2/L.103 (1973).

<sup>52</sup> See UN Document A/AC.1/1047 (Oct 15, 1974), Article IX of Latin America Draft Treaty. While positions on this issue have shifted, it is still a major point for debate.

<sup>53</sup> J.J. Hahn, "Development Toward a Regime For Control of Remote Sensing from Outer Space", in Journal of Interna-



First, developing countries are entering into mature, mutually beneficial resource exploitation relationships with foreign interests, without forswearing their rights to such ultimate sanctions as nationalization and/or expropriation. Second, the physical control of resources and of access to resource sites are the trump cards, not possession of tentative and unverified data. Third, as developing countries acquire their own remote sensing expertise, whether indigenous or procured from outside consultants, the margin of information disadvantage can lose a good measure of its significance.<sup>54</sup>

The position of countries desiring a restricted dissemination policy runs directly counter to the U.S. position, which is centered around the dissemination of remote sensing data to all interested parties "on an equitable, timely and non-discriminatory basis."<sup>55</sup> The U.S. further argues that the imposition of dissemination limits would undermine two of the most important benefits of satellite remote sensing --the broad synoptic view of multi-national resources and the development of global monitoring systems.<sup>56</sup> The U.S. believes that support of a restricted dissemination regime neglects to consider the "tremendous benefits of remote sensing and the fact that exploitation cannot really take

-----

tinal Law and Economics, no. 3, 1978, pg 449.

<sup>54</sup> NAS Study, op.cit., pg 147-148.

<sup>55</sup> Hosenball Speech to the American Bar Association, 8/8/73, in Hood, Kimball and Kay, A Global Earth Observation System For Earth Resources: Problems and Prospects, (American Society of International Law, Washington D.C., 1977, pg. 51.

<sup>56</sup> NAS, op. cit., pg 147.

place without the knowledge and effective cooperation of the country in which the resources lie."<sup>57</sup>

For some U.S. decision makers, however, concerns over dissemination impede the development of a global information system.<sup>58</sup> These concerns also lay the base for international pressures/demands on U.S. decision makers. This presents a policy dilemma for U.S. decision makers. On the one hand, in the U.S., the position is taken that the U.S. government ought to take the lead in establishing remote sensing resource information as an international public good--taking the information out of the hands of large U.S. companies that might utilize such data/information.<sup>59</sup> In fact, this position may well be in accordance with U.S. domestic policy which allows open access to the data--and an open international dissemination system would simply extend the domestic system. On the other hand, the private sector--if it is to become involved in the ownership of the system--will likely apply for some rights to the data, either through an extension of copyright laws or by making the data somehow proprietary, in order to make the system profitable. While this would not directly violate the open dissemination

-----

<sup>57</sup> Hosenball Speech, pg. 50.

<sup>58</sup> These include, among others, Senator Stevenson of Illinois, and Howard Kurtz. See next footnote.

<sup>59</sup> Kurtz, "Remote Sensing of Environment, An Interdisciplinary Journal, Vol 6, Number 2, Editorial.

policy, it would make it harder and more expensive to use Landsat.

Generally then, within the U.S., policy makers are confronted with competing goals; first, for a government run global information system; and second, for a private sector dissemination system which will increase prices and encourage the use of Landsat data for economic gain. These competing goals interlock with the developing countries desire for reliability and continuity of data, which are free from political pressures. Here too, is a policy paradox. To avoid economic exploitation the elites of developing countries and of the U.S. may want governments involved in regulating the dissemination of information and its use; but to avoid political exploitation of developing countries, greater authority and control for the operation of the Landsat system should be located in the private sector,<sup>60</sup> or in some international organization.

-----

<sup>60</sup> This is not to say, unfortunately, that the private sector wouldn't use Landsat to politically exploit developing countries, however the fear is that they will use the data less for blackmail and more for economic exploitation of resources.

## 5.6 THE ISSUES OF DEPENDENCE AND ACCOUNTABILITY

The issues of dependence and accountability will probably gain importance and move to the center of the policy stage as the Landsat technology and market matures. The issue of dependence is clearly stated as follows:

Should remote sensing technology fulfill its promise, it will become indispensable for many countries. User nations will have made significant investments in facilities of various kinds. They will have geared their data gathering and decision making processes, both in the public and private sectors, to the peculiar characteristics and assured availability of satellite imagery. Their interest in the stability and continuity of the service on which their domestic systems will have come to rely will consequently be considerable.<sup>61</sup>

The impact that this issue has on the development of a remote sensing market in developing countries is tied up with the notion of international dependency. Most third world nations do not want, for political and practical reasons to become dependent on one source of resource information vital to their national planning--particularly a source over which they have no control. As dependence increases, the demand for a voice in the planning of the system will grow. While in the short run the U.S. is in a dominant position, the development of competitors in Japan and France could dilute the U.S. hold on the market for remotely sensed data. If the U.S. doesn't consider the needs of developing countries, and assure continuity and reliability of the

-----

<sup>61</sup> NAS Study, op. cit., pgs 149-150.

data, then when alternative sources become available--the likelihood of a decreased U.S. market share increases.

The question of accountability suggests to some policy makers that the U.S. should acknowledge its use of space to obtain resource information as the use of a "public commons" for the purpose of obtaining a "public good." The use of an international commons is to avail oneself of a public good. Here, the international community view is that in the use of such a commons, a nation should be accountable not only to itself but to the interests of the larger world community.

This issue of accountability, it seems to me, is much like the dependence issue. If developing countries demand a participatory role in the development of a remote sensing system, then by that simple fact they will have taken part in the collective exploitation of the international commons, and the issue of accountability will be easier to confront. While at first blush this seems to be consistent with the U.S. policy of developing space for the benefit of all mankind, it unfortunately runs into the problem of enticing the U.S. private sector to participate in the development of an operational system. For if the research and development, and the market development that an operational system demands are dictated by international actors the ability to make a profit could be impaired as the private sector is unlikely

to want to be held accountable to the desires of international actors. This position also overlooks the tremendous money spent by the U.S. to make the exploitation of the commons possible in the first place.

In general then, while the U.S. has a monopoly at present over the technology of remote sensing from space, and only naturally wants to exploit that monopoly, the developing countries (representing part of a viable market) wish some say in the development of an operational system. While the monopolist, in general, has to worry less than the small competitor about user demands--in the case of Landsat this may not hold. First, the technological monopoly is likely to be short-term; and second, the market monopoly assumes that a market exists to be monopolized. If the technology does not meet the needs of the user, the user might not buy what the technology has to offer, and the monopoly will have nothing to monopolize.

The idea is the same as before: the U.S., in building a viable market in developing countries, must take into consideration, to some extent, the desires of the user--in this case the developing world. To do this, the U.S. must try to develop cooperative relationships, while at the same time encouraging developing countries to adopt Landsat technology.

## 6. POLICY ISSUES AND TRADE OFFS

The primary issue facing American decision-makers throughout the debate over an operational earth resource sensing system is the type of government/industry relationship that will come to own and operate that system. The market for Landsat data and products is important to this issue because many of the decisions on the pricing, timing and financial arrangements for the operational system depend on that market.<sup>62</sup> Unfortunately, a good market analysis has not yet been done. The developing country market is an important potential market, but is poorly understood. This final section undertakes some tentative analysis of the impact of U.S. policy decisions on the growth of that market.

In general, there are four goals guiding the development of Landsat Policy. Two are international: the desire of some U.S. policy makers to develop a global information system to be used for peaceful purposes; and the desire of developing countries to manage their own development. Two are domestic: the need to revitalize the U.S. economy in an economically hostile world; and the desire to move the operational Landsat system into the private sector.<sup>63</sup>

-----

<sup>62</sup> See PSIS and Issues and Options Paper.

<sup>63</sup> see Introduction to this paper, pgs. 4-8.

Three primary policy issues will be addressed from the perspective of these four goals: pricing, data ownership, and system characteristics. The issues are simply stated. First, should the price of Landsat data be increased? If so, how much and how fast? Second, who should own rights to the data? The U.S. Government, the U.S. private sector, the user, or some U.N. body? Third, what type of system should be flown? One with maximum technical sophistication and highest cost, or a less sophisticated and cheaper system? These three issues can now be analyzed in light of the four policy goals just mentioned.

Policy I. Pricing: In general an increase in the price of Landsat data and products will influence the international factors negatively and the domestic factors positively (at least in the short-term). (1) If a market price is charged for Landsat data, fewer Landsat applications will be cost-effective and this will dampen market growth. (2) An increase in the price of data is essential to capitalizing on the U.S. technological lead and encouraging private sector participation in the operational system. Thus, while a price increase is essential for private sector participation it may dampen the market building process.

In the short-term the building of the user community may be more important to the building of a long-term market than is



capitalizing on a short-term market. Further, as competitors come along, a high price might allow them to capture some or all of the market. In general, in thinking about the price of Landsat products, one ought to consider the design of the system which will be extremely important in determining which users are most likely to use the system, and the sensitivity of those users to an increase in product prices. Hence an understanding of the markets sensitivity to various system configurations and to price increases is essential.

Policy II: Data Ownership: If data ownership is taken out of the hands of the government and put into the hands of the private sector, international objectives will be negatively influenced and domestic objectives will be positively influenced. (1) If the government gives the private sector data ownership rights, the ideal of a global information system will be unachievable. Such a policy would make data proprietary and not reproducible by and for everyone. While proprietary rights are important if private sector participation, is to be encouraged, such rights discourage an open, global system. (2) Generally, the building of a user market would be hampered by making the data proprietary as the re-use or reproduction of data might be made illegal (although difficult to control). Developing countries who might be encouraged at not having political strings on the data

(although the government seems to regulate much international trade and technology transfer), may be wary of "economic imperialism". (3) To bring the maximum return on sales of Landsat data, ownership of the data and general copyright laws are seen (particularly by industry) as essential. A decision in this area should include an analysis of whether a market exists that could support a private sector enterprise (in the best of all possible worlds). If there is a potentially viable market, then some form of data protection may be necessary. If no viable market exists, then a redirection of the program toward the meeting of global objectives might be in order. Finally, this question is tied up with the pricing question, data ownership should not be undertaken without raising the price of Landsat data.

Policy III: System Characteristics: In general, the more powerful<sup>64</sup> a system, the greater the positive impact on the international objectives, and the more difficult it will become (in the short run) to meet domestic objectives. (1) The more powerful the sensing capabilities of the satellite, the more useful it will be for global applications, and the more important will become global coordination. (2) As the satellite system becomes more powerful, it will meet more and more user needs, thereby expanding the use of, and

-----

<sup>64</sup> Powerful referring to a system including maximum possible spatial and spectral resolution, plus stereoscopic capabilities.

interest in the data. By tailoring the system to user needs, the users will be more likely to support the system.

(3) The cost of a powerful satellite becomes increasingly expensive. As this occurs, the potential for recouping U.S. investment, particularly in the next decade, becomes more problematic. (4) An increase in the the systems power, and hence in the systems cost, will make it harder to entice the private sector into ownership of the system. In general a powerful system is likely to generate a larger user community and make it harder in the short-term to encourage private sector participation. The U.S. should consider pursuing a more powerful system for several reasons; first, if they don't the French and Japanese are likely to try and take away whatever market exists in developing countries by tailoring their systems to developing countries needs; second, the U.S. is likely to fall technologically behind foreign competitors; and third, in the long run it is likely that a more powerful satellite will be essential to the building of a viable market, as it will be usable throughout the development project cycle, and hence, for more repetitive uses.

Further issues can also be analyzed from this perspective. My general conclusion is that the building of a viable market in the short run, coupled with a strong R&D effort to maintain U.S. leadership in this area will insure a viable

situation for private sector participation in the long run. Short run factors pushing for "market now" strategies may hinder U.S. efforts to build global relations and to build a viable market. Policy makers must now get a firm hold on the market and its sensitivities to these various issues. In particular, I suggest the following areas for market study:

4

1. The extent to which the present market is supported by U.S. aid programs;
2. The probability that a viable market can be sustained through the continuation of such aid;
3. The determination of the real value of information from Landsat;
4. Market sensitivity to a projected four-fold increase in Landsat products;
5. Market sensitivity to the use of and cost of digital processing and interpretation techniques;
6. Market sensitivity to effective or non-existent user training programs;
7. Market sensitivity to different configurations for the operational satellite system;

8. The potential for aggregating a user market in developing countries which will be of sufficient size to help entice the private sector to take over some or all of the development and ownership of the system.

This paper has been an effort, in part, to understand the special problems inherent in developing a market for Landsat data and products in developing countries. Because of the great potential in developing countries, because of the importance to policy makers of understanding that market, and because it is so poorly understood--this should be an important item on the list of needed analysis for policy makers. Only when this and in fact the entire Landsat market is better understood, will policy makers be able to undertake to design the appropriate private/public sector interface for an operational Landsat system.

Appendix A  
RESOURCE INFORMATION AREAS

Briefly, some of the areas where increased resource information is needed are:

1. Agriculture--the need for accurate estimates of crop acreage and yields is critical to national and international agricultural planning. Land-use capability maps will prove useful in making decisions regarding what crops to plant and where, irrigation and drainage. As such, soils maps, hydrologic maps, and general terrain maps will be important in constructing land-use capability maps for agricultural planning.<sup>65</sup>

As an aside, goals for global agricultural surveys might include:

- a) A global survey of cultivated areas, agricultural systems and crops to provide the statistical base for planning agricultural development and information for specific development projects, and to keep such information up to date.

-----  
<sup>65</sup> NAS, op. cit., pg 38.

b) A survey of tropical Africa and South-east Asia of shifting cultivation and within these, the areas under cultivation and fallow, and as far as possible the age classes of the fallow as a guide to lengthening excessively short fallow periods and the resultant reduction of yield, due to increasing population pressure.

c) A global and desert locust belt survey to monitor conditions, mainly of weather and vegetation, potentially favorable for the development of crop pest epidemics in order to improve their control

2. Rangeland Management--Rangelands are important contributors to world-wide protein food supplies as they furnish grasslands for feeding of bovine, sheep, and goat populations. Between 40 and 60 per cent of the earth's land mass is covered with rangelands. They represent the largest reservoir of land available for conversion to more direct human use.<sup>66</sup>

However, due to rangeland characteristics, information is and has been difficult to obtain. "Practically no information has been available on rangeland conditions in developing regions."<sup>67</sup> One necessary

-----  
<sup>66</sup> User Needs, op. cit., pg. 15.

<sup>67</sup> Ibid., pg. 17.

component, then, for improving rangeland management is the acquisition of information on when, how much, and how long forage will be available.

However, this information should be in the hands of range managers within about 10 days after it is acquired. Like most plant systems, rangeland vegetation exhibits rapid changes in condition at certain seasons of the year and livestock movement can take appreciable time. Hence a need associated with the gathering of rangeland data is for the establishment of an effective system for rapid dissemination of rangeland information.<sup>68</sup>

Better range management information will enable

- a) more accurate determination of germination and drying periods for planning movement of grazing animals to or from annual grassland ranges;
  - b) predictions of the remaining length of the green feed period made early enough to plan more efficiently for alternative sources of livestock feed;
  - c) comparison of conditions and relative forage production between grazing areas within a season, and comparison of conditions and productivity for a given area between seasons;
  - d) determination of the time when dry forage creates a fire hazard to better allocate men and equipment for fire suppression.
- 

<sup>68</sup> Ibid., pg 17.



3. Forest Management--Information is needed in monitoring clear cutting of forest by developing countries, mapping burn areas, monitoring logging and detection of pests and diseases. In several developing countries the extent of deforestation has reached levels far exceeding the calculations of the countries involved. Since forests are an important national and international resource, information about them becomes all the more important in the face of present inadequate information sources.

Management activities require information on quantitative standing timber values, patterns of stand structure and conditions, and dynamic response of the forest. However, traditional data acquisition and processing procedures have generally been inadequate, slow, and too costly to produce the necessary information to meet current and projected needs of forest managers.<sup>69</sup> Forest resource inventory information is generally needed in 1 to 10 year cycles for forecasting forest trends and in the development of long-term national programs. However, for some management purposes, more frequent observations may be required, including:

- i) detection of stresses in forest vegetation to permit remedial action before major damage occurs;
- ii) monitoring of forest harvesting progress, particularly in remote areas of developing countries;
- iii) determining forest response to silviculture practices such as fertilization and reforestation.

-----  
<sup>69</sup> Ibid., pg. 17.

4. Water Resources Management--Since water is required by all humans for irrigation, sanitation, power generation, and industrial processing, and the demands for water in all these application areas is increasing in the face of growing world populations and increased demands for quality of life improvements, water resources information is essential. "Efficient water management may require a varied set of meteorological and hydrological data: the volume of runoff and the variability of streamflows; the geological, soil, and vegetation characteristics of watersheds, possibly including data on the extent and depth of high mountain snow; the area watered by irrigation; and the rate of agricultural use of water.<sup>70</sup> Improved water management capabilities require:

- a) maps of surface water bodies as small as several hectares to determine water reserves;
- b) mapping major river systems to determine their spatial variation and the seasonability of stream flow;
- c) surveying and monitoring of surface conditions in large watersheds;

-----  
<sup>70</sup> Ibid. pg 17.

- d) mapping of the extent of snow and ice-covered areas for runoff estimation;
- e) mapping of the extent and duration of flooded areas as a basis for flood protection and land capability assessment;
- f) surveying of estuary and coastal hydrologic features to determine dynamic water circulation patterns and water turbidity;
- g) surveying of surface features as a guide to ground-water assessment.<sup>71</sup>

Such information will enable improved water resource management in these respects:

- i) improved regulation of reservoirs for efficient hydropower generation, flood control, and water supply on the basis of better snowmelt and runoff prediction;
- ii) improved planning of regional water distribution based on better monitoring of surface water amount and soil moisture;

-----  
<sup>71</sup> Ibid. pg 18.

iii) better decisions regarding irrigation management for crops through improved knowledge of water consumption and supplies;

iv) more efficient and economic siting of wells.<sup>72</sup>

5. Minerals--Many parts of the world remain geologically unexplored. As developing nations (and all nations for that matter) become increasingly aware of the importance of minerals for development, and aware that they do not possess the detailed minerals maps and information that developed countries do-- and as they seek to assert their rights and ownership over the development of minerals in their country, mineral resource information becomes essential. Geological mapping and terrain studies are a first step toward mineral exploration and provide a base for better resource investment decisions.<sup>73</sup>

6. Energy--In an effort to cope with high and rising prices of energy, information on alternative energy sources is becoming critical. For example, the potential for hydrologlectric and geothermal energy

-----

<sup>72</sup> NAS. op. cit., pg 73.

<sup>73</sup> Smith, Willim. "Landsat Applications in Less Developed Areas", in Remote Sensing Applications for Mineral Exploration. Strousberg, Penn., John Wiley and Sons, 1976, pg. 279.

is/will be based largely on geologic and hydrological data and such data only becomes available through resource surveys. However, the primary thrusts of applied geology have come where the discipline is mature, the exploration area is accessible and the cost of exploration is moderate.<sup>74</sup>

Because of these factors a disproportionate percentage of the known mineral deposits are found in the temperate and arid regions of the world. However, there is no geological reason why economic mineral deposits should not be present in the tropical regions in the same relative abundance as elsewhere.<sup>75</sup>

7. Cartography-- There is a general need for basic maps for purposes of national and regional resource planning. This includes information on urban sprawl, agricultural land withdrawal, siting of transportation and power systems, etc. General mapping needs are widespread:

Generally every agency within a Government utilizes maps in one form or another for resource inventories, land use planning and control, urban area planning, energy development and conservation, coastal zone and wetlands management, environmental protection, etc. This is because Governments

-----

<sup>74</sup> Ibid, pg. 285.

<sup>75</sup> NAS Study, op. cit., pg 20,21.

cannot effectively function without precise knowledge of the boundaries or the area under their jurisdiction, the physical characteristics of the country, the position and size of urban areas, the communication network, etc.<sup>76</sup>

---

<sup>76</sup> Ibid. pg. 13.

## Appendix B

### THE MAPPING POTENTIAL OF LANDSAT

The application of Landsat data and image interpretation to many fields has begun to be demonstrated in developing countries. The actual utilization of the data to help make better or different decisions is less well demonstrated, and in fact more difficult--this question is taken up in part 2 of this study. Here, I am more concerned with what types of Landsat data can be produced and what their potential applicability is; what is Landsats potential for solving resource information problems in developing countries?

In general Landsat data can be used to prepare photomaps at scales of 1:250,000 and smaller, particularly with state-of-the-art processing techniques. Generally for production of basic maps at scales of 1:500,000 and smaller, Landsats 1 and 2 (and Landsat 3 is) were quite acceptable. With advanced digital processing techniques larger scale maps can be produced (up to 1:24,000), but the level of detailed information which can be drawn from these maps may make them unusable for some applications. What my research has shown, is that it is generally impossible to say whether

or not Landsat can do this or do that apriori to knowing what the problem is. For example, in some countries needing general reconnaissance surveys Landsat may turn out to be inappropriate because of the cloud cover. In another area where detailed information is needed, advance ground processing capabilities may make Landsat data quite useful, particularly in simply structured resource areas. What follows are some examples of what has been done with Landsat in developing countries to date. The examples are meant to be illustrative of the rich, however problem oriented, potential of Landsat.

#### Bolivia

1. The Instituto Geografico Militar has prepared photomaps at scale 1:500,000 from Landsat frames. In addition, an uncontrolled mosaic covering the whole territory of Bolivia at scale 1:500,000 was produced using 65 Landsat frames.
2. Three different government institutions are involved in geologic studies using Landsat. Complete regional geologic maps covering one third of the country at 1:250,000 have been developed. Using Landsat images, the government was able to select a number of potential areas for oil exploration.



3. The government has also completed a map of the drainage system in Bolivia at scale 1:1,000,000. It is currently combining this information with geomorphical data and geological data in order to identify areas of potential ground water accumulation;
4. Landsat imagery has also been used to produce a forest map of the country at scale 1:2,500,000. For further details maps at scales 1:250,000 are now being produced.
5. The government has done reconnaissance soils surveys at scales 1:250,000.
6. A comprehensive preparatory effort has been made to define land cover and land use types corresponding to the country's conditions. The result has been a land cover/land use map at scale 1:4,000,000.<sup>77</sup>

#### Australia

1. Landsat colour composites are being used in the compilation of land-use maps at a scale 1:5,000,000 for the preparation of an Atlas of Australian resources;

-----

<sup>77</sup> UN, "Report on the UN/FAO Regional Training Seminar on the Applications of Remote Sensing from Satellite", La Paz, Bolivia, 1977, A/AC.105/210, pg. 5.

2. A complete set of Landsat aerial photomaps at a scale 1:500,000 covering the whole of the state of South Australia has recently been completed. These maps are intended for use in an ecological survey of that state;
3. The Division of National Mapping has also completed photomaps of the Australian Antarctic Territory<sup>4</sup> at scales of 1:500,000 and 1:250,000 from Landsat imagery. These maps cover the main areas of topographical interest such as coastlines and features free of ice and snow.<sup>78</sup>
4. A comprehensive land-use mapping program is underway, initially to cover the South-Eastern part of Australia. Three "seperate overlays showing land cover, land tenure, and land use are being compiled. False colour Landsat images of Bands 4,5 and 7 have been found to provide the degree of detail needed to distinguish the different land cover patterns in most cases. Where finer detail is required conventional aerial photographs are used."<sup>79</sup>

-----

<sup>78</sup> J.F. Ryan, "Applications of Remote Sensing in Australia", ERIM Symposium, Vol 12, op. cit., pg 47.

<sup>79</sup> Ryan, Op. cit., pg 69.

Argentina A number of projects were carried out in the province of Santa Cruz, using Landsat images for soils and actual land use studies as well as for economic and social studies of the area influenced by the construction of a big dam. For soils and geomorphological studies, Landsat imagery at scale 1:500,000 proved to be best suited under the topographic conditions existing in the Santa Cruz province.<sup>80</sup>

#### Chile

Visual analysis of Landsat imagery at scale 1:500,000 and 1:1,000,000 was used in 1975 for the inventory of natural resources in the regions of Tarapaca and Antofagasta covering an area of 212,000 square kilometers. The geological interpretation of the imagery resulted in the identification of 10 areas with linear structures that justify a detailed prospecting on the ground. Geomorphologists identified 21 land forms each composed of 35 material components. For the first time vegetal associations could be mapped in these regions, discriminating seven formations and their respective subgroups. The interpretation of the Landsat imagery also allowed the delineation of several climatic zones and the separation of 43 watersheds. Pedologists were able to differentiate 56 soil associations.<sup>81</sup>

---

<sup>80</sup> UN, "Applications of Remote Sensing From Satellite", op. cit., pg 7.

<sup>81</sup> Ibid., pg. 8.

Malaysia Land use mapping at scales 1:100,000 and 1:500,000 has been carried out. Using band 5 "broad land use delineations were possible and rice, rubber, mangrove, forest and mixed agriculture were easily discernable. Band 5 gives greater tonal differences in vegetation cover than the other bands."<sup>82</sup>

## Brazil

Flat areas with thin forest cover were considered to best suited for a transition into range land or agricultural land with the exception of very wet or swampy areas that had to be separated out. The selection of potential areas for the envisaged land use transition was made after studying the drainage pattern, the humidity and the density of forest cover in Landsat images of band 5 and 7."<sup>83</sup>

-----

<sup>82</sup> Salleh, Mehd. "Remote Sensing Activities in Malaysia", in ERIM Symposium, vol 12, op.cit., pg 135.

<sup>83</sup> UN, "Applications of Remote Sensing From Space", op.cit., pg 7.

## Appendix C

### LANDSAT POLICY APPLICATIONS

#### Soils Mapping and Agriculture

As part of a national water study of Mexico, soils maps at a scale of 1:1,000,000 intended to show the location and extent of the country's potentially arable soil resources, have been prepared largely with the aid of Landsat data. Two sets of Landsat color transparencies for most of the country provided the basis for the mapping project, which covered present land use as well as soil capability. The study of present land use covering the whole country took two years and cost \$200,000. One significant finding was that 6.3 million hectares were in a state of advanced erosion. The study of soil capability covered 45 million hectares and was completed in one year. Thematic maps were extracted from the satellite data to indicate potential for cultivated crops and range, soil depths, wetness, slope, erosion hazard, and irrigation prospects. The maps now offer the Mexican Government a guide to the soils that are considered good or fair for development and that deserve more detailed study. For instance it seemed clear from the maps that some areas used for rice might be better suited for other crops and that the soils of the Gulf Coast area would be more suitable for rice production.<sup>84</sup>

-----

<sup>84</sup> See A.A. Klingbiel and V.I. Myers, "An ERTS-Based Land Resource Inventory for Mexico's National Water Study", Soil Conservation, 4:18-20 (November 1974) and H. Garduno, R Garcia Lagos and F. Garcia Simo, "Present and Potential Land-Use Mapping in Mexico", Proceedings of the NASA Earth Resources Symposium Houston Texas, June 1975.

### Rangeland Management

A study in the Arusha region of Tanzania employed Landsat data successfully in delineating boundaries for 550 distinct landscape units in a 32,000 square mile area on the basis of landform and vegetation characteristics. Fourteen grassland types of varying suitability for forage were recognized in the Landsat data. These delineations fortified with detailed sampling information provided by aerial photography and on-site inspections, have identified promising areas for range, agricultural, and ground water development.<sup>85</sup>

### Forest Management

In Brazil, Landsat imagery has been used to monitor a program for controlled development of large areas of the Amazonian forest for various purposes, especially cattle grazing. Landowners, with the help of the government are permitted to cut down trees up to a third of their land holdings. Routine and systematic use of Landsat imagery has proved to be the only economic way of enforcing the terms of the government assistance contracts and of monitoring and controlling the volume of tree cutting.<sup>86</sup>

### Water Resources Management

Two series of Landsat images taken five weeks apart made an important contribution to a multi-stage study of the annual flooding of the Lower Magdalena-Cauca River Basin in Columbia. The sequential images made possible a classification of the river marginal lakes according to their role in tempering the water wave and their potential for serving as reservoir basins. The Landsat imagery was particularly successful in identifying the lakes that dried up in the 5-week period. The Landsat data, together with aerial photographs and side-looking radar images, yielded information needed by governmental planners to determine the most practical means to reclaim land in the lower part of the inundated areas.<sup>87</sup>

-----

<sup>85</sup> C.E. Poulton, et. al., "Potential Groundwater and Land Resource Analysis for Planning and Development", Unpublished report prepared for the Agency for International Development, 1975--cited in NAS study.

<sup>86</sup> NAS study, op. cit., pg. 69.

## Geologic Survey and Mineral and Petroleum Exploration

On the basis of a rock-type classification map produced by digital computer processing of Landsat data, 30 prospect sites were chosen in a Pakistan area. Out of the 19 sites visited, 5 yielded evidence of surface mineralization, indicating the possibility of an enriched zone of copper.<sup>88</sup>

## Land Use--Urban and Regional Planning

Comparative analysis of two sets of Landsat scenes covering the state of Orissa in India has yielded a substantial volume of land-use information of direct value to state resource managers and agricultural planners. The earlier imagery were studied primarily to locate areas of present and potential two-crop rice production, but also to identify as many land-use categories as possible. Indian soil technicians, foresters, and geologists, trained by a world bank team in interpreting satellite imagery by field survey methods, succeeded in recognizing about half of the thirty categories sought. The two sets of Landsat scenes highlighted the differences between dry and wet season agricultural patterns and identified promising areas for conversion to irrigated two-crop production. The Landsat data also indicated areas suitable for dams or barrages showed the extent of forest cutting in the highlands and coastal regions, provided a new base for checking the accuracy of crop acreage estimates done by conventional means, and showed the changing course of the Mahanade River and its tributaries from the time of the last topographic mapping two or three decades earlier.<sup>89</sup>

-----

<sup>87</sup> E. Van Es, H. Gomez and R Soeters, "An Inundaton Study of the Lower Magdalena-Cauca Basin" in Houston Symposium, op. cit., 2295-2297.

<sup>88</sup> NAS Study, op. cit. pg 77.

<sup>89</sup> NAS study, op. cit., pg 79.

Appendix D  
FOR AGRICULTURAL CROPS

10-20 minutes

Observe the advancing waterline in croplands during disastrous floods. Observe the start of locust flights in agricultural areas.

10-20 hours

Map progress of crops as an aid to crop identification using "crop calendars" and to estimating date to begin harvesting operations.

10-20 months

Facilitate annual inspection of crop rotation and of compliance with federal requirements for benefit payments.

10-20 years

Observe growth and mortality rates in orchards.

20-100 years

Observe shifting cultivation patterns.

For Timber Stands

10-20 minutes

Detect the start of forest fires during periods when there is a high "Fire Danger Rating."

10-20 hours

Map perimeter of on-going forest fires.

10-20 days

Detect start of insect outbreaks in timber stands.



10-20 months

Facilitate annual inspection of fire-breaks.

10-20 years

Observe growth and mortality rates in timber stands.

20-100 years

Observe plant succession trends in the forest.

For Rangeland Forage

10-20 minutes

Detect the start of rangeland fires during periods when there is a high "Fire Danger Rating."

10-20 hours

Map perimeter of on-going rangeland fires.

10-20 days

Update information on "Range Readiness" for grazing.

10-20 months

Facilitate annual inspection of fire-breaks.

10-20 years

Observe signs of range deterioration and study the spread of noxious weeds.

20-100 years

Observe plant succession trends on rangelands.

For Other Vegetation (mainly shrubs)

10-20 minutes

Detect the start of brushfield fires during periods when there is a high "Fire Danger Rating."

10-20 hours

Map perimeter of on-going brushfield fires.

10-20 days

Update information on times of flowering and pollen production in relation to the bee industry and to hay fever problems.

10-20 months

Facilitate inspection of fire-breaks.

10-20 years

Observe changes in "Edge Effect" of brushfields that affect suitability as wildlife habitat.

20-100 years

Observe plant succession trends in brushfields.

## Appendix E

### SIMPLE VS. COMPLEX RESOURCE AREAS

Characteristics of simply structured versus complexly structured areas in relation to natural resources.

#### Simply Structured Areas

##### Agricultural Vegetation

1. Fields large, regularly shaped, usually homogeneous with respect to crop condition.
2. Few competing crops and cultural practices.
3. Little interspersion of cropland with noncropland.
4. All fields of a given crop planted on about the same date and hence developing in essentially the same seasonal pattern.

##### Range and Forest Vegetation

1. Blocks of rangeland and forestland are large and relatively homogeneous.
2. Elevational range is low to moderate and hence vegetation of a given type tends to develop with essentially the same seasonal pattern.

3. Few vegetation types present, all adapted to the same elevational and climatic range.
4. Topography flat to gently rolling so that few vegetational differences are the result of differences in slope and aspect.
5. Cultural practices with respect to range and timber resources are few and uniform.

#### Geology, Soils, and Hydrology

1. Geologic, soil, and hydrologic formations are relatively large, simple, discrete, and homogeneous.

#### Complexly Structured Areas

##### A. Agricultural Vegetation

1. Fields small, irregularly shaped, frequently heterogeneous with respect to crop condition.
2. Many competing crops and cultural practices.
3. Much interspersion of cropland with noncropland.
4. Fields of a given crop planted on many different dates and hence developing with many different seasonal patterns.

B. Range and Forest Vegetation

1. Blocks of rangeland and forestland are small and relatively heterogeneous.
2. Elevational range is high to very high and hence vegetation of a given type tends to develop with many different seasonal patterns.
3. Many vegetation types present, each adapted to a particular elevational and climatic range.
4. Topography steep so that many vegetational differences are the result of differences in slope and aspect.
5. Cultural practices with respect to range and timber resources are many and varied.

C. Geology, Soils, and Hydrology

1. Geologic, soil, and hydrologic formations are relatively small, complex, intermingled, and heterogeneous.

## Appendix F

### METHODS FOR ORGANIZING NATIONAL REMOTE SENSING PROGRAMS

A first method involves the development of remote sensing programs within an existing technical agency concerned primarily with a particular resource.

In Argentina, the primary interest of the first Landsat investigation has been to test space sensing capability to determine acreage and conditions of crops, especially wheat. The Ministry of Agriculture and Livestock has established a remote sensing operation with an associated data processing center capable of both manual and computer processing. Program plans include work in range management, agricultural land use maps, and mapping of drainage networks.<sup>90</sup>

Secondly, in many countries remote sensing programs have centered themselves in a lead agency that showed early interest in using Landsat data.

Brazil's highly advanced and well-equipped program is lodged in the National Institute of Space Research. It operates a ground station which records more than 350 Landsat images a day, provides data on agriculture and forestry to the Ministry of Agriculture, on geology to Ministry of Mines and Energy, and on a broad range of subjects to the Ministry of the Interior, all of which contribute to the Institute's budget for these services. Other clients now include private firms and neighboring countries. The Institute has ties with educational institutions and runs its own seminars, workshops, and courses on remote sensing.<sup>91</sup>

-----

<sup>90</sup> NAS Study, op. cit. pg. 125, 126.

Third, some countries have organized coordinating committees to organize users and technical capabilities prior to the establishment of a full-blown program.

The National Committee on Mineral Exploration and Survey Operations in the Philippines has served as a coordinating agency for remote sensing activities. The coordinating body includes several bureaus including some out of the Departments of Agriculture and Natural Resources, The Coast and Geodetic Survey, The Air Force, and The University of the Philippines. Thus far, this committee has dealt with Landsat programs in the areas of geology, land use, hydrology, cartography and mineral exploration.<sup>94</sup>

Finally some countries have simply developed new agencies to organize and take responsibility for remote sensing activities.

The Indian Government established the National Remote Sensing Agency in the Department of Science and Technology in 1975. It has plans to orbit an earth survey satellite with a return beam vidicon sensor at some point in the future. Its goals are to guide remote sensing research, maintain data banks, publish research results, organize training programs, and conduct resource surveys for use by the countries development planners.<sup>95</sup>

-----

<sup>91</sup> NAS Study, pg 126.

<sup>92</sup> ERIM Symposium, Vol 12, See pg 128-138.

<sup>93</sup> ERIM Symposium, Vol 12, see pg. 43-53.